

Geophysical technology transfer symposium: Russian airborne geophysics and remote sensing

By ALEX BECKER
*University of California
Berkeley, California*

A unique symposium, Russian Airborne Geophysical and Remote Sensing Technology, was convened in September 1992 at the Colorado School of Mines. Its purpose was to expose Americans to the latest Russian technology, survey practices, and future development plans in, principally, airborne magnetics and gravimetry. A minor part of the symposium, however, was devoted to airborne radar (SAR) and laser (LIDAR) measurements. While the majority of the papers related to applied airborne geophysics with an accent on the technical implications of the instrumentation, data acquisition and processing for geophysical exploration and oceanography, a few papers reviewed Russian work in atmospheric and earth physics. Of particular interest here was a paper by Y.A. Kopytenko which reported on a possible correlation between a local rise in intensity of geomagnetic ULF variations and the onset of an earthquake in the region of the observation station.

The symposium was jointly convened by the National Oceanographic and Atmospheric Administration (NOAA), Colorado School of Mines, and the Russian Academy of Sciences (RAS). The cochairs were Warren Dewhurst of NOAA and S.N. Domaratskij of RAS. About 30 papers were presented over a period of three days by the 35 Russian scientists in attendance. The audience was comprised of about 120 US scientists and a few from Canada.

Most of the participants (40 percent) represented US industry and a third of those were specifically tied to the US petroleum fraternity. Understandably, the next significant fraction of attendees (25 percent) was professionally related to US Navy laboratories and oceanographic units. The balance of the audi-

ence had a diversity of professional interests with most being tied to US government earth science units (USGS, the Bureau of Mines, etc.) and national laboratories. Academia was notably absent, possibly because of the concurrent beginning of the fall term.

Perhaps the most unusual aspect of the conference was the means of transportation used by the Russian delegates from Moscow to Denver. They arrived at Stapleton Airport aboard a massive IL-76MD jet transport. The logistic and geophysical features of this plane, which is used for airborne surveys in Russia, were summarized in a paper by T.G. Musiniantz of the Institute of Precise Instrumentation. He reported that the IL-76MD has a gross takeoff weight of 119 tons, can carry a payload of about 40 tons, has a fuel autonomy of 10 hours, and a range of 8200 km. Its long range and minimum speed of 220 km/hr make it well suited for high altitude (>300 m) data acquisition in polar regions. Finally, we were told that the aircraft can operate from unpaved and relatively short (1500 m) strips where it can land on wheels or on skis.

The aircraft was opened for a visit by conference participants. In addition to the usual complement of navigation and communications instruments (including GPS), the aircraft had three geophysical/remote sensing instrument bays. Each consisted of three standard (19 in width, 6 ft height) racks for electronics and a seat and console for the operator. A PC-type computer was available for in-flight data acquisition and processing. Conventional magnetic tape is used for recording.

Musiniantz' paper indicated that the plane carried the following complement of sensors: camera, LIDAR, IR radiome-

ter, SLR (four bands—4, 23, 70, and 240 nm), gravimeter (Graviton model), and magnetometers (vector type).

Although the provisions for mounting the remote sensing instrument heads in outboard pods attached to the fuselage were clearly visible, the antenna and sensors were not mounted and could not be seen. We also noted the fact that, while a significant number of conference papers were related to magnetometer construction/ mounting/compensation, no magnetometers were mounted on the IL-76, nor were any of the airframe modifications usually needed for a magnetometer installation evident. Likewise, no magnetic compensation equipment was seen. The only working demonstrations aboard the aircraft included a PC with software for processing images and a conventional stabilized vibrating string gravimeter which we were told was soon to be replaced by a superior model. All in all, the limited display of airborne equipment was somewhat of a disappointment.

On the technical side, however, the visitors were shown a torsion fiber observatory magnetometer of unusual sensitivity (1 pT [pico Tesla] or 0.01" of arc). The torsion angle detection principle was not disclosed. Finally, any technical shortcomings of the visit were much lessened by the warm hospitality of the flight crew who treated all visitors to a taste of Russian vodka and caviar.

Airborne magnetic surveys. Domaratskij gave a historical summary on Russian accomplishments over the past 56 years. He reviewed progress from early airborne measurements (1936-55) with an earth inductor to the use of fluxgates during the 1955-75 period

and went on to proton and absorption magnetometers now in use. It was not clear whether the magnetometers were installed inboard or whether they were housed in a towed bird. It appears that both options are current and that research is still being done on bird stability and/or location as well as on compensation systems for inboard installations. In fact, a subsequent paper by V.I. Feigels described a laser-based system for accurate positioning of the bird while a paper by V.K. Palamarchuk alluded to a complex but highly accurate compensation system based on the simultaneous use of a number of magnetometers within the same aircraft.

By the end of 1975, large parts, if not most, of the Soviet Union were surveyed at a scale of 1:200 000. From then on, activity was increased as they started to produce maps at a scale of 1:50 000. At one point in the 1975-90 period, over 70 aircraft/helicopters were equipped for the task. We contrast this number with about 30 aircraft available in the West during the same time period.

Modern installations were described in a series of papers by Musiniantz, Palamarchuk, and Y.G. Turbin. These reports gave an overview of the flying laboratory concept which the Russians use as it applied to the IL-76, the IL-18, and the AN-12 platform. The instrumentation for the latter two aircraft shows a commonality of principle in that each can carry at least one gravimeter in addition to an accurate multiple magnetometer installation. A provision is also made for additional remote sensing instruments which are installed as needed. It should also be noted that the Russians have developed a working GPS navigation system that can be used for positioning the survey aircraft. The GLONAS system was described by E.P. Gurianov of the Leninetz Concern. An absolute accuracy of about ± 75 m and a differential accuracy of ± 5 m was claimed.

Not much conference attention was given to magnetic sensor fabrication. It appears that the Russian magnetometers of different kinds (fluxgate, nuclear, and optical) are comparable in quality to those available in the West so that sensor noise is not a problem. Of interest here, however, is a very accurate magnetometer calibration and noise measurement system described by V. Averkiev. It was pointed out by V.I. Pochtarev that vector measurements are more informative than measurements of

the total field. In all cases, however, it was realized (as reported by Palamarchuk) that survey accuracy depends mainly on proper data acquisition including good system compensation, positioning and removal of diurnal variations. They, as we, have found that the diurnal problem can not be solved by using base stations but must be addressed by repeat airborne observations during the course of the survey.

The question of instrument compensation was addressed in some detail by V.A. Blednov who appears to have made a detailed analysis of this problem. He concludes that one can isolate the correct value of the ambient magnetic field measured in the near presence of magnetic and/or magnetized objects by using a large number of sensors. The measurements are processed according to a scheme called the Method of Definition of Angular Components (MDAC). No specific mention, however, was made of compensation for eddy currents induced in the aircraft skin as it flies through the earth's field. Nonetheless, the Russians must be able to eliminate this noise source if one is to believe the 5-10 pT noise figure quoted for the IL-18 installation.

The subject of compilation of magnetic maps was treated at some length in a series of presentations by Valentina Kolesova of SPbFIZMIRAN. In the course of these reports, we were once again exposed to a review of airborne and shipborne coverage for the former Soviet Union. Maps are made at all scales. They include large scale maps of the geomagnetic field to small scale (1:10 000) maps used for mineral exploration. The map compilation process starts with careful planning and setting of specifications for the survey. Once the measurements are made, the results are separated into the geomagnetic, regional, and local components. Much care is taken to have correct estimates of the first component by means of 176 observatory stations which are surveyed every five years.

Prior to separation into the regional and local components, a spectral (SPAN) analysis is made of the profile data. The result is a "SPANOGRAM" which in appearance and principle is entire analogous to the Western SONOGRAM that was much in vogue for vibration and speech analysis in the '50s. It appears that the output is most useful for interpreting the data with respect to the underlying large scale tectonic structure.

Nonetheless, the SPAN technique can be applied at any scale. Specifically, mention was made of its use for identifying short wavelength anomalies in oil fields. These are sometimes associated with very shallow magnetic deposits.

Air- and shipborne gravimetry. Because of the high accuracy that was reported, the three papers for this topic were of great interest to the audience. The talks were given by V.O. Bagramyantz, who reviewed the results, and G.P. Nessenjuk, who described the instrument construction. The gravimeters are based on a torsion wire or a vibrating string sensor with an optoelectronic readout. The instrument is mounted on a gyro-stabilized platform which is held level to better than 30" of arc. Measurement accuracy is superior to ± 0.5 mGal.

Excellent results at sea and the air were reported by Bagramyantz who showed a well defined 0.5 mGal anomaly observed near Sakhalin Island and a 0.2 mGal anomaly in another region where it was allocated to an oil reservoir. He put routine survey accuracy at ± 0.5 -2.0 mGal for shipborne surveys, ± 1 mGal for helicopter surveys, and ± 3 mGal for fixed wing surveys.

Remote sensing. About 10 papers were devoted to a description of atmospheric and remote sensing equipment and techniques. Atmospheric observations were discussed by Kopytenko, Raspopov and Boyarskij. The last report was perhaps of most topical interest as it was based on the first-hand experience of an Antarctic crossing where surface temperature and atmospheric ozone content were correlated. One set of reports, by Y.A. Kozko and V.V. Saveliev, dealt with SAR acquisition and processing. These included a good description of the correlation techniques used by the Russians for target identification. Apparently, they find these techniques very useful for many applications which range from SAR image analysis to fingerprint identification. The last group of papers in this area was given by Feigels and Y.A. Kopilovich. Here we had a summary description of the Russian LIDAR system and its applications. One type of laser transmitter operates in the 511-518 nm green region and emits 3 ns pulses at a 16 000

(Russian airborne continued on p. 801)

(Russian airborne continued from p. 785)

pps repetition rate. Peak power is 0.3 MW, the diameter of the receiver optics can vary from 0.3–0.7 m in diameter. In good conditions, they report a range of 30–40 m in relatively clear water. The applications include detection of fish and measurements of chlorophyll content in water as well as pollutant detection. Without any real substantiation, it was suggested that Russian LIDAR optics are superior to their American equivalents while the opposite is true of the associated processing electronics.

Conclusions. This was an excellent conference in that it did give American scientists a direct exposure to Russian geophysical and remote sensing techniques and technology. The stated objectives of the conference were therefore largely achieved and the organizers merit congratulations as do the session chairmen and Norman Harthill of CSM who attended so well to the myriad of logistic details that accompany the staging of this type of event.

It is difficult to summarize in a paragraph or two all the significant findings that were presented. From a personal viewpoint, however, this observer has retained the following list of Russian practices which are, to my knowledge, not very common in the West:

- Use of large, long-range flying laboratories equipped with a multiplicity of sensors
- Practical, direct applications, for LIDAR and SAR data
- Highly accurate airborne gravimetry
- Use of multiple magnetometers for reducing installation noise
- Use of correlation analysis for target detection in SAR and magnetic data (A paper by D. Kalmykov referred to a statistical analysis of a number of coincident airborne survey maps—mag, grav, etc.—for the purpose of extracting mineral target parameters.)

Although the conference reports did not present indisputable evidence for the validity of some of the claims, these techniques are certainly of sufficient interest to merit further investigation. **LE**